A LEARNING RESOURCE

Unit Standard 16340 v3

Biology of the New Zealand Greenshell™ Mussel

(Perna canaliculus)

SEAFOOD INDUSTRY TRAINING ORGANISATION

The New Zealand Seafood Industry Council Ltd

Contents

This resource was updated for SITO by AquaBio Consultants Ltd, Auckland

Introduction

This book provides support information to prepare for:

Unit standard 16340 (version 3) Level 3, credits 5.
Describe the biology of the New Zealand Greenshell Mussel (kutai, kuku)

This learning resource and unit standard 16340 covers:

1. The description of Greenshell^{TM} mussel:
   (a) the scientific name of the species
   (b) three features that distinguish it from other common mussel species
   (c) its habitat
   (d) its geographical location in New Zealand.

2. The location, identification & function of the main anatomical features of Greenshell^{TM} mussel, plus how to determine its sex:
   left & right shell, periostacum, byssus (beard), foot, gills, labial palps, adductor muscle, gut, gonad, mantle, sense organs.

3. A description of Greenshell^{TM} mussel's:
   (a) stages of the life cycle
   (b) feeding method and food sources at each life cycle stage
   (c) stages of the reproductive cycle including gonad development & natural triggers for spawning.

4. A description of the factors that impact on growth of Greenshell^{TM} mussels, including:
   (a) two methods of measuring the growth
   (b) four factors that can affect the growth
   (factors such as: water temperature, water quality, food quality, food availability, mussel age, stress)
   (c) how each factor impacts on mussel growth rate.

5. A description of abnormal features and/or behaviours that could indicate potential Greenshell^{TM} mussel health issues:
   (a) five abnormal features and/or behaviours that could indicate a potential health issue
   (b) the action to take if abnormal features and/or behaviours are identified
   (c) two reasons why this action is important.

This learning resource is designed to accompany a course that includes examination of live mussels in their shells.

Here is some information about how the book is set out:

- Each section matches a separate element of the unit standard. So, for example, Section 1 of the book covers all of element 1.

- Activities to assist in learning are presented throughout the text in *blue italics*. So if you see writing in blue italics, you know that it is something that you have to do.

- **Key words or phrases** have been marked in **bold.** This is to help you revise the information easily.

- Self test questions are included at the end of each block of learning, covering the knowledge required for the unit standard.

- Throughout the text the sources of information are referenced using superscript numbers in square brackets – like this: [27]. These numbers refer to a list of references that is presented in the back of the book. So if you want more detail about a particular subject, note the number in the bracket, and then use the number to find the reference from the "References" section at the end of the book.

1. Describe the Greenshell™ Mussel

1A Naming Mussels

In order to specifically identify a type of mussel it is necessary to use the **scientific name**. Every species of animal or plant has its own unique, scientific name. The same scientific names are used throughout the world.

Scientific names contain two parts: **first, the name of the genus to which the organism belongs, followed by the species name.** (For an explanation of how organisms are scientifically classified into these genus/species groupings, see Appendix I).

If two animals have the same *Genus* name, it indicates that they are very closely related. This part of the name may be shared by close relatives, like a surname. However the two-part name is always unique to just one species.

By scientific convention the scientific name is always written in *italics* or underlined. The '*Genus*' name is always written with a capital letter and the '*species*' name with a small letter.

The scientific name often uses Latin words, which generally have some meaning relevant to the species being named. For example, words may be used which represent the country where the species is found or describe a distinguishing feature. Sometimes the species may be named after the person who discovered it.

Common names however are simply the **names by which the animal is "commonly" known** and can **vary from country to country and even between people**. Each mussel species may be known by several different common names.

Perna canaliculus, commonly known as the **green-lipped mussel**, is the species of mussel farmed in New Zealand. Farmed green-lipped mussels are also called **Greenshell™ mussels**. This is a name trademarked by the NZ Mussel Industry Council on behalf of the New Zealand mussel farming industry. Only *Perna canaliculus* farmed in New Zealand may be called Greenshell™ mussels.

1B Distinguishing Features, Habitat and Geographic Location of Greenshell™ Mussels

There are 16 species of mussel in New Zealand, but the two most well known are the two edible types: the blue mussel (*Mytilus galloprovincialis*)[1] and the **Greenshell™ mussel** (***Perna canaliculus***).

The Greenshell™ mussel is easy to distinguish from the blue mussel as it has a **distinctive green lip along the inside shell margin** that is absent in all other New Zealand mussels. The outside of the **shell of adults is green-dark brown/black**, (the blue mussel is blue-black). The shells of Greenshell™ mussels are slightly **more rectangular in shape, with more prominent angles than those of the blue mussel.** The Greenshell™ mussel has only **one muscle that holds its two shells closed** (the posterior adductor muscle – see Section 2.2 later), whereas the blue mussel has two (posterior and anterior adductor muscles). For larger mussels, size can also act as a distinguishing feature, as the Greenshell™ mussel can grow to a larger size than the other species in New Zealand. It can grow up to 240 mm long, compared to a maximum size of 100 mm in the next largest species, the blue mussel.

The Greenshell™ mussel is found in low inter-tidal areas, and sub-tidally to over 50 metres. It prefers a sub-tidal habitat (that is, it is most commonly found living in places that are under the water all the time). It attaches to wharf piles, rock faces (and culture ropes on mussel farms), and is also found amongst seaweed beds and in deeper water over mud or sand bottoms. It can tolerate strong wave action.

The Greenshell™ mussel (*Perna canaliculus*) is found throughout New Zealand. It is native to New Zealand, and is found only here.

For further information, some of the more common mussel species in New Zealand are listed in Appendix II, including both their scientific and common names. Pictures of each species, distinguishing features and habitats are also given.

ACTIVITY 1
Using live mussels, examine the appearance of a Greenshell™ mussel and at least one other species of mussel.

Can you identify three differences between the two species of mussel?

1.

2.

3.

2A External Features of Mussels – location, identification and function

Bivalves (including mussels) have a soft body which is flattened from side to side [2]. The body is protected by a **valve** (shell) positioned on either side. The two valves (shells) are joined together by a hinge.

What does the shell do?

The mussel shell has several functions:

- It acts as an **external skeleton** for the attachment of muscles.
- It **protects** the soft body from drying out when the mussel is out of the water, and from being eaten by predators.
- It helps to **control the water flow** into the mussel, and thus the number of particles passing over the gills [2].

Figure 1 below is a simplified drawing of an unopened mussel that shows its exterior features. The labels in boxes in this diagram give the names of the different directions on a mussel: in simple language that is easy to remember: dorsal = back; ventral = front; anterior = head or top; posterior = tail or bottom).

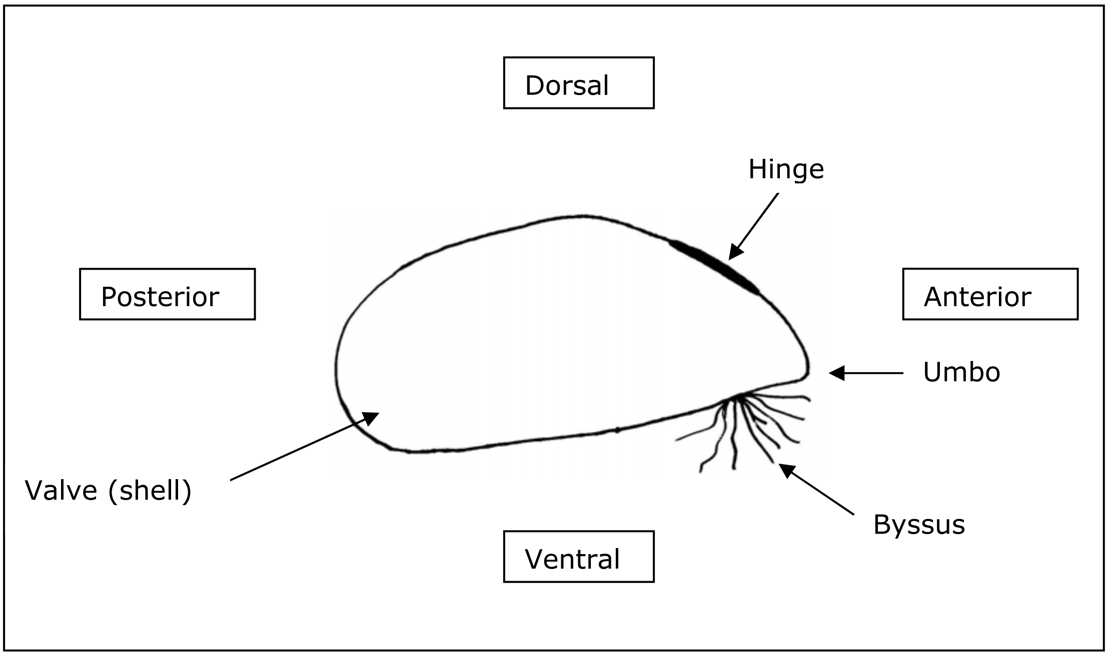


Figure 1: The external features of a Greenshell™ mussel.

The two valves (shells) are joined by a flexible ligament (the **hinge**). The **hinge** is located on the **dorsal** (back) side of the animal. The hinge ligament is constructed of horny conchiolin (a kind of protein matrix). It lies within the valves, and is designed to spring the valves apart. At the shell edge beside the hinge there is a series of small ridges or teeth that match with corresponding hollows in the opposing valve to prevent any sideways movement of the valves.

Often the **byssus (beard)** is obvious hanging outside the shell on the anterior **ventral** surface opposite the hinge. The mussel uses these byssal threads (beard) to **attach itself to surfaces such as rocks**. It can release its hold on these threads and secrete new ones at any time, enabling it to move or alter position. The amount of byssus produced varies with the environment the mussel lives in (e.g. the strength of current it has to resist).

2A External Features of Mussels – location, identification and function - continued

The mussel shell is typically pointed at the **umbo**, which is found at the front or **anterior** end of the animal. The shell is rounded at the rear or **posterior** end. The shape and nature of the shell are quite variable depending on the environment in which the mussel has been grown. Rings of growth may be evident in the shell. These are caused by changes in environmental conditions that impact on the rate of growth. (Factors that can affect the growth of mussels are covered in section 4 of this resource).

In mussels the shell valves are equal in size and roughly triangular in shape. When holding a mussel with the umbo pointing upwards, and the hinge or dorsal surface facing towards you, the valve on your left is the '**left valve**' and the valve on your right is the '**right valve**'. In other bivalves, such as oysters or scallops, in which the valves are not the same shape, the left valve is usually the cupped valve that contains the body.

ACTIVITY 2	
Examine a live mussel. Identify the:	*left valve* *right valve* *hinge* *umbo* *byssus*

What is the shell made of?

The main component of the mussel shell is the mineral calcium carbonate. The calcium for shell growth is taken up from the food, or directly from the surrounding seawater [2].

The shell is composed of three layers as described in Table 1 below. Note that the green colour of the Greenshell™ mussel comes from the thin outer layer called the **periostracum**. This layer helps to **protect the shell**.

Periostracum	Outer layer of shell	Composed mostly of protein (organic). Protective external layer - relatively thin. This layer gives the green colour to *Perna*, but it can become almost black.
Prismatic Layers	Middle layer of shell	The thickest layer. Is often chalky in nature. Made mostly of inorganic calcium carbonate (90%) in a crystalline structure (calcite or aragonite) mixed with small amount of protein substance called conchiolin.
Nacreous Layer	Inner layer of shell	Thin, often shiny or lustrous - the pearl forming layer. Very hard. Also made of calcium carbonate but in this part of the shell the crystals are in sheets which reflect and bend light giving a shimmery appearance.

Table 1. Description of the three different layers of mussel shell.

2B Internal Features of Mussels – location, identification and function

ACTIVITY 3
To complete this section of learning it is helpful to actually look at a mussel as you work through the book. Open a mussel carefully by removing the RIGHT valve (shell) by cutting the muscle that holds the valves together. Try to cut the muscle as close to the RIGHT valve as possible. Remove the RIGHT valve so that the mussel rests in the LEFT valve, and lies the same direction as the one in Figure 2 below.

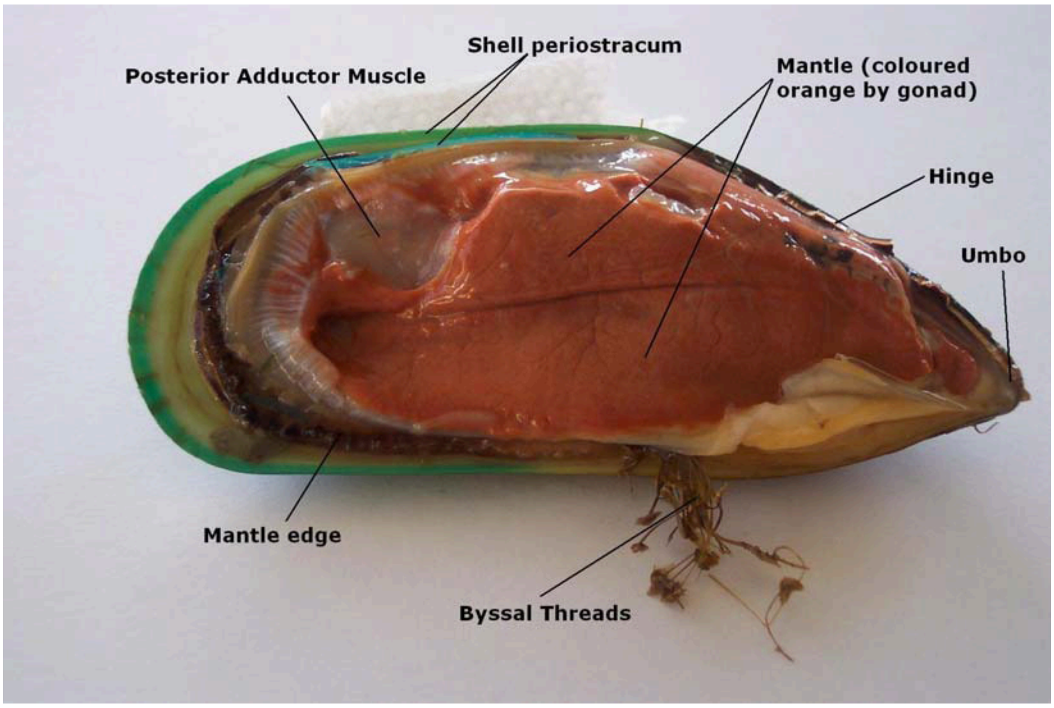


Figure 2: ***Photograph of a ripe female Greenshell™ mussel with the right valve (shell) removed. The major anatomical features that are visible in this view are labelled. [Diagram by AquaBio Consultants Ltd]***

ACTIVITY 3
Look at your mussel carefully and see if you locate the features labelled in Figure 2 as follows:

- The big muscle that you will have cut through to open the mussel is called the **posterior adductor muscle.** It **controls the opening and closing of the valves (shells)** of the mussel. It holds the valves closed, and controls how widely the valves open. When it is relaxed, the spring of the hinge causes the valves to open (that's why dead mussels gape open).

- The **mantle** is the layer of tissue that covers the mussel on each side of the body. It lies next to the inside of the shell. The mantle consists of connective tissue with haemolymph (blood) vessels, nerves and muscles that are particularly well developed near the mantle edges [2]. The mantle is one of the parts of the mussel that contains **gonads** (**reproductive tissue that produces eggs in females or sperm in males**). The mantle also has a function in **energy storage**. The mantle edge is usually dark in colour (black to brown) [3]. However, most of the mantle is coloured by the gonad inside it. Because mussel **eggs are coloured orange**, mature female mussels have orange-coloured mantles. Mature male mussels have cream mantles because the **sperm is cream-coloured**. If the gonad doesn't contain any eggs or sperm (for example in immature or spawned out mussels), the mantle appears cream-coloured also.

ACTIVITY 4
a. Are you able to identify whether the mussel you have opened is a male or a female?
b. Notice the dark-coloured, frilly edge to most of the mantle

2B Internal Features of Mussels – location, identification and function – continued

The **mantle edge** (the frilly part) is separated into three folds: The outer one, next to the shell, **produces the shell** (this is discussed in more detail in the Section 4); the middle fold has a **muscular function and controls water flow into the mussel,** and the inner fold has a **sensory** function[4].

ACTIVITY 5
*Check around the edge of the shell & mantle and look for evidence of new **periostracum**. (This will look like very thin strips of green plastic).*

- The two sides of the mantle (known as the **mantle lobes**), which surround the rest of the mussel body, are fused in several places along the mantle edge in order to help separate the **inhalant** (incoming) and **exhalant** (outgoing) water currents – that is, they separate the water going into the mussel from the water coming out. Look at Figure 3 below to see the position of these currents and the places where the mantle lobes are fused. In this figure the direction of the inhalant current is marked in yellow, and the position of the exhalant current is marked in red. The region between the mantle lobes that receives the inhalant current is called the **inhalant chamber** (enclosed by the yellow dashes in Figure 3), while the region from which the water exits the mussel is called the **exhalant chamber**. The mantle lobes are fused from the anterior edge of the exhalant chamber all along the dorsal side of the mussel around to the anterior of the inhalant chamber.

ACTIVITY 6
a. Examine the mantle on your opened mussel. Locate the places where the mantle lobes join & identify the inhalant chamber (large side) and the smaller exhalant chamber
b. Does the mantle edge look the same in both chambers?

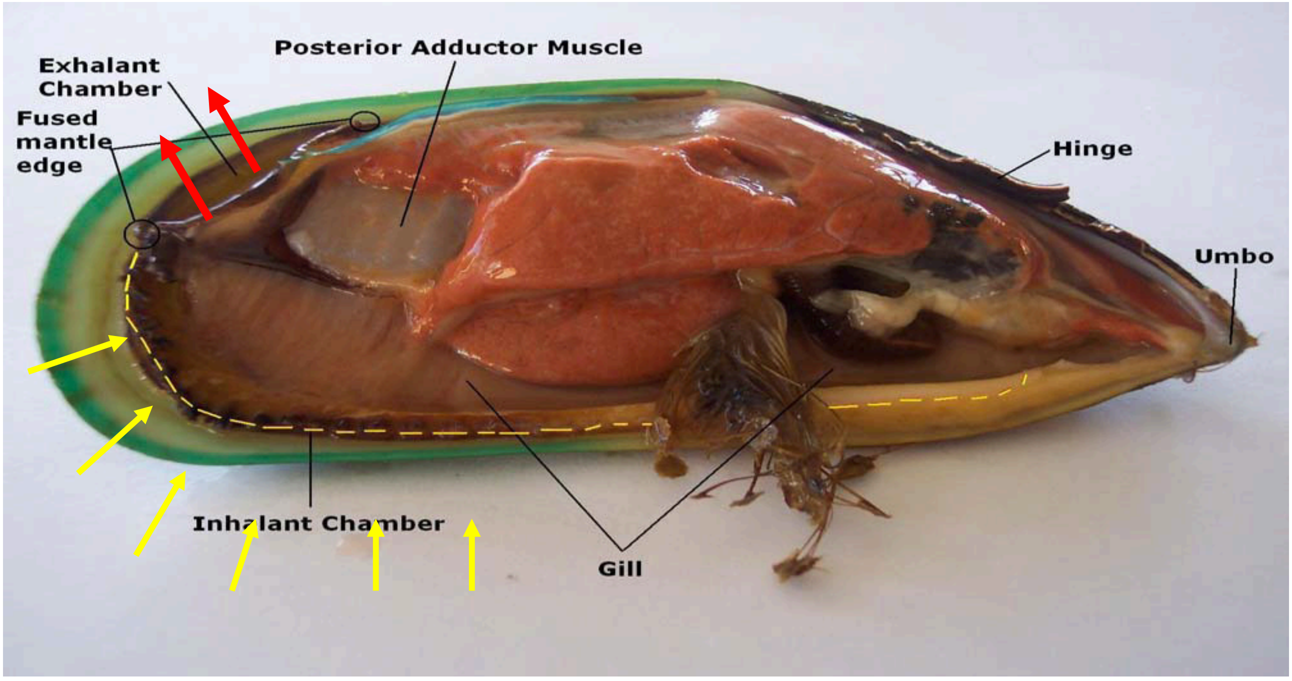


Figure 3: Photograph of a Greenshell™ mussel with ventral right mantle lobe and right gill cut away, showing the inhalant and exhalant chambers. Yellow dashed lines indicate the position of the inhalant chamber. Yellow arrows show the direction of the inhalant current, and the red arrows the direction of the exhalant current. [Diagram by AquaBio Consultants Ltd]

- The frilly bits that you can see on the edge of the mantle are the **sensory papillae** on the inner fold of the mantle edge (see Figure 4 below). They can **sense chemical changes in the water**, such as changes in salinity or the presence of toxic substances. The sensory papillae can also sense **touch**. Sensory papillae are numerous around the inhalant chamber, and absent from the exhalant chamber [2]. *Why do you think this is so?*

2B Internal Features of Mussels – location, identification and function – continued

ACTIVITY 6
Find the sensory papillae of your opened mussel.

Figure 4: A feeding Greenshell™ mussel showing the frilly mantle edge, with the sensory papillae visible.

ACTIVITY 7
Figure 5 on the following page shows a mussel with the right mantle lobe and right gills cut away. You can see the same things in your opened mussel by holding back the right mantle lobe and gills.

*First, pull back the right mantle lobe to reveal the **gills** of the mussel. (See Figure 5 on the following page for the location of the gills).*

- The **gills** (often called "ctenidia" (pronounced ten-id-ee-a) by scientists) are the ridged, light cream/tan coloured structures lying along the ventral side of the mussel. There are two sets of paired gills. They are folded to form a W shape on either side of the body. The gills have important functions in both **gas exchange for respiration** (like lungs for breathing in humans) and in **obtaining food** by filtering water [2].

- Like humans, **mussels require oxygen (O_2)** to live, and **produce carbon dioxide (CO_2) as waste**. The surface of the gills is the most important site for such gas exchange. Mussels absorb oxygen from the water through the surface of the gills, and carbon dioxide is released back into the water from blood in the gills.

- Covering the gills is a layer of small hair-like structures called **cilia** (pronounced "sill-ee-a"), which move water, and particles from the water, by beating together rhythmically in waves. The action of the cilia draws water into the mussel (the inhalant water current), across the gills and out through the exhalant chamber (the exhalant water current). This **water current brings both oxygen and food to the mussel**. Some cells on the gills produce **mucus**, which traps particles from the water. **Particles trapped in mucus on the gills are moved by cilia along special pathways towards the mouth**.

- At the anterior end of the gills are two pairs of light coloured leaf-shaped appendages called **labial palps.** These **lie on either side of the mouth**. (See Figure 5 on the following page for the location of the labial palps. See also Figure 6 which shows a close-up view of the anterior of the mussel). These palps have an important **sensory function** as they **sort the particles** trapped in the mucus, separating potential food from unwanted particles. Food particles are then transported to the **mouth,** while particles that are rejected are bound in mucus and dropped back into the inhalant chamber to be ejected out of the mussel [2]. (Further detail about feeding in mussels is presented in Section 3.1 on page 17).

2B Internal Features of Mussels – location, identification and function – continued

ACTIVITY 8
Pull back the right gills of your mussel to find the labial palps, and look for the mouth located between them.

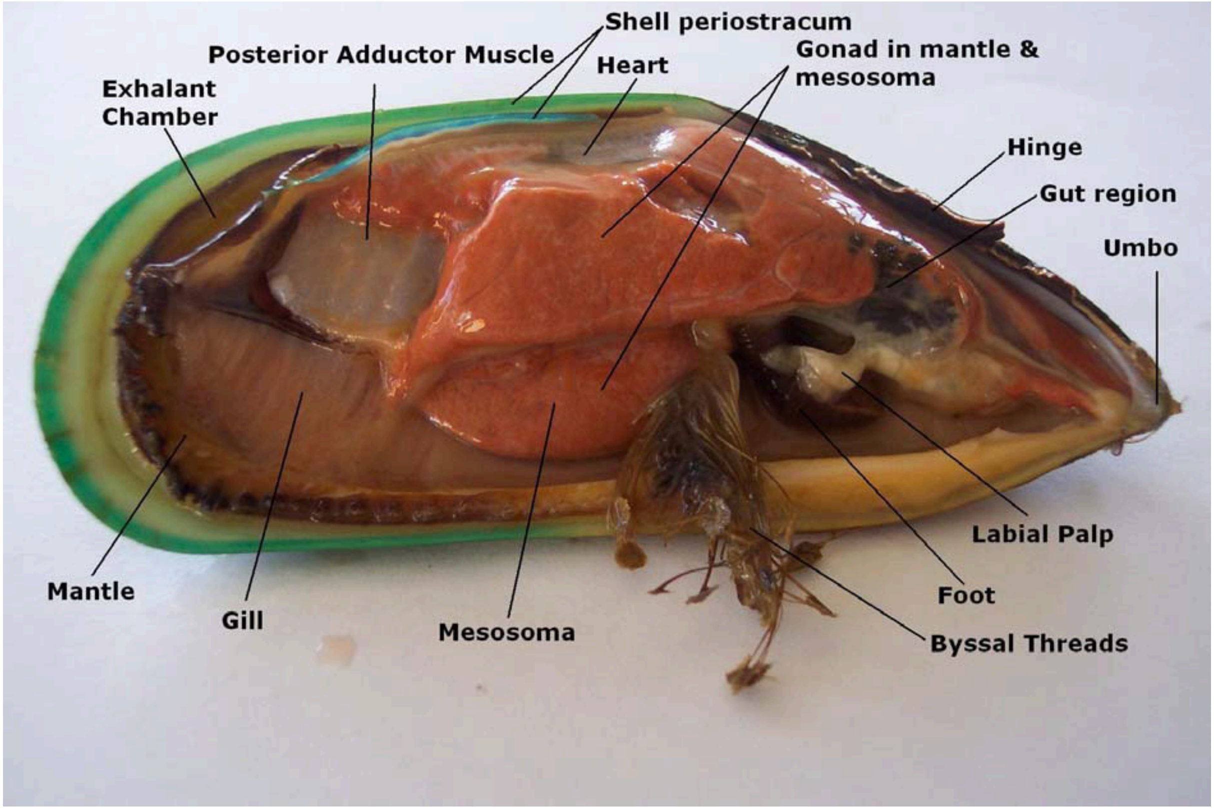


Figure 5: Photograph of a Greenshell™ mussel with the right valve, right mantle and right gill removed. [Diagram by AquaBio Consultants Ltd]

- The **dark brown tissue** that forms a significant portion of the body of the mussel is part of the **gut region** (see Figure 5). The gut region is where **digestion** occurs. Digestion involves breaking down food particles into simple chemicals that can be used by the mussel. The main parts of the gut are **the stomach**, the **digestive gland** and the **intestine**. Very simply, **digestion occurs in the stomach and digestive gland** (which is the green-brown tissue that you can see if you cut into a mussel in the gut region). The **intestine compacts the waste products of digestion to form faeces, and carries them to the anus, where they are discharged into the exhalant current**.

ACTIVITY 9
Can you see the gut region of your mussel? (When mussels are very fat, the gut region can sometimes become hidden under the gonad tissue).

- Lying between the pair of gills is the **mesosoma** (meaning "middle body") (see Figure 5). Like the tissue in the mantle, the tissue of the mesosoma is important for **energy storage** and **reproduction**. You can see that the mussel photographed in Figure 5 has gonadal tissue in the mesosoma - the mesosoma in this mussel is **orange-coloured** because it is a female and the gonad contains **eggs**.

ACTIVITY 10
Locate the mesosoma between the gills of your mussel

2B Internal Features of Mussels – location, identification and function – continued

- On the dorsal side of the mussel, just anterior to the posterior adductor muscle, lies the pericardial cavity containing the **heart**. The heart **pumps blood around the body of the mussel.** The membrane covering the pericardial cavity is transparent, and in live mussels the heart can sometimes be seen beating (at a rate of around 25 times per minute). Note that the blood (known as haemolymph, pronounced "hee-mo-limpf") of mussels is virtually colourless, so you won't be able to see it.

ACTIVITY 11
Can you locate the heart in your mussel? (If mussels are very fat, it can be difficult to see.) Is it beating?

- The **foot** of the mussel is a dark brown-coloured structure that lies at the anterior of the body on the ventral side (see Figure 6 on the next page). The foot is muscular, with a groove running down its length. It has several important roles. It allows the mussel to **move**, and has an important **sensory function** in that it feels and tastes the surfaces that it touches. The foot is used by the mussel to find surfaces that are suitable to attach to. When a suitable surface is found, **the mussel uses the foot to attach itself**. At the base (body end) of the foot is the **byssal gland** which produces the **byssal threads**. In order to attach itself a mussel reaches out with its foot to find a good attachment point. It then ejects a fluid from the **byssal gland** down through the groove in the foot. Upon contact with seawater this fluid goes hard and forms a **byssal thread** (that is, one of the threads that is part of the byssus). The foot is then removed, leaving the thread anchored to the attachment point at one end, and to the byssal gland of the foot at the other end [5]. In this way each thread is individually created. The **foot** also allows the mussel to **shift position** by extending out and attaching byssal threads in the desired direction, and then pulling the mussel along to these new anchor points.

ACTIVITY 12
Find the foot and the groove which helps create the byssal threads. Feel the texture of the foot and note how muscular it is.

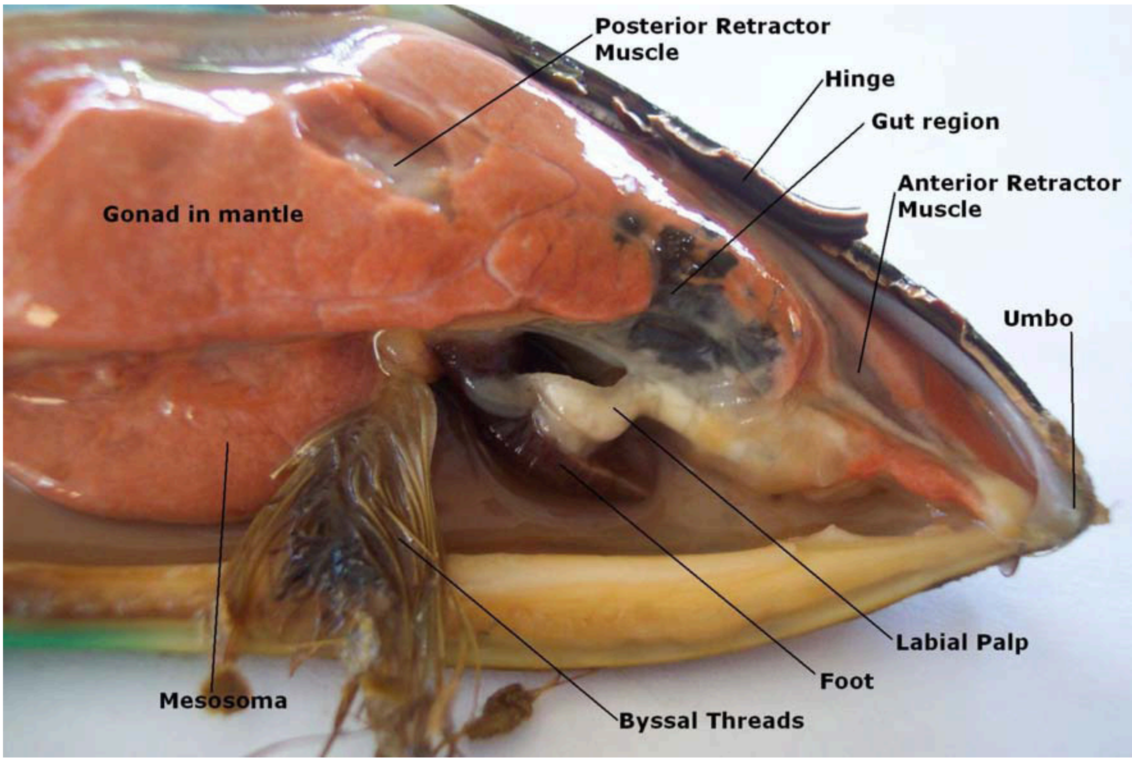


Figure 6: Photograph of the anterior of a Greenshell™ mussel with the right valve, right mantle and right gill removed. [Diagram by AquaBio Consultants Ltd]

2C Summary of the function of some of the anatomical features of Greenshell™ mussels:

Feature:	Function:
Valves (shells)	• The mussel **valves (shells)** have several functions: o They act as an **external skeleton** for the **attachment of muscles**. o They **protect the soft body** of the mussel from drying out when the mussel is out of water, and from predation. o They help to **control the flow of water** into the mussel.
Periostracum	• The **periostracum** is the thin external layer of the shell. In Greenshell™ mussels it is **coloured green**. It helps to **protect** the other layers of the shell.
Byssus (beard)	• The mussel uses the **byssus** (beard, or byssal threads) to **attach itself to hard surfaces**. It can release its hold on the byssal threads at any time, enabling it to move or alter position.
Foot	• The **foot** has an important **sensory function** in that it **feels and tastes the surfaces** that it touches. • **Byssal threads** are secreted from the **byssal gland** at the base of the **foot**. • The **foot** can help the mussel **shift its position** by extending out and attaching byssal threads to surfaces in the desired direction, and then releasing its hold on the old byssal threads and pulling the mussel body up to the new anchor points.
Mantle	• Contains tissue important for **energy storage and reproduction** • The **mantle edge** is separated into three folds: the outer one next to the shell is concerned with **shell secretion**; the middle fold has a **muscular function and controls water flow into the mussel,** while the inner fold is **sensory** in function[4]. The **sensory papillae** on the inner fold of the mantle edge test the quality of the incoming water. (That is why they are numerous around the inhalant chamber, and absent from the exhalant chamber [2]).
Gonad	• The **gonad** is the **reproductive tissue** that is located in the mantle and mesosoma, and surrounding the gut. - In **females** the gonads produce **eggs** (**orange coloured**) and in **males** they produce **sperm** (**cream coloured)**. Gonad that does not contain mature eggs or sperm is also cream coloured.
Posterior adductor muscle	• The function of the **posterior adductor muscle** is to **hold the valves (shells) closed** and **control how widely the valves open**.
Gills	• The gills have major functions in **respiration** and **feeding** in mussels. • **Respiration:** The **gills** are the **main surface through which mussels "breathe"**. Oxygen (O_2) is absorbed from the water into the blood of mussels across the surface of the gills, and carbon dioxide (CO_2) is released back into the water from the gills. • **Feeding:** The gills also **filter out particles of potential food from the water**. **Cilia** on the gills **move water and potential food particles** by beating together rhythmically in waves. Water is drawn into the mussel and across the gills (the inhalant water current) and out through the exhalant chamber. **Food is trapped in mucus** on the gills, and moved by cilia along special pathways to towards the labial palps and mouth.
Labial palps	• Located on either side of the mouth, the **labial palps** have an important **sensory function.** The cilia on their surface **sort the particles** trapped in the mucus.
Gut	• The **gut** is where **digestion** of food occurs. Digestion involves **breaking down food particles into simple chemicals** that can be used by the mussel. These simple chemicals such as simple sugars are **absorbed into the mussel through the walls of the gut**, and provide the mussel with **nutrients for growth and energy.** • The main parts of the gut are the **stomach**, the **digestive gland**, and the **intestine**. **Digestion occurs in the stomach and digestive gland** (which is the green-brown tissue that you can see if you cut into a mussel in the gut region). The **intestine compacts the waste products of digestion, and carries them to the anus in the exhalant chamber to be discharged as faeces**.

3. Feeding, Reproductive Cycle and Life Cycle

3A Feeding

The process of feeding

In Section 2 we described the role of the gills in feeding. In this section we discuss feeding in mussels in more detail. A practical exercise is included to allow you to observe the path of particles on the gills of a live adult mussel.

Mussels are "**filter feeders"**, which means that they take in seawater from the surrounding environment and "filter" out particles present in the water. As discussed previously, the cilia on the gills beat together rhythmically in waves, drawing water into the mussel (the inhalant current), across the gills and out through the exhalant chamber (the exhalant current) (Refer back to Figure 3 for a diagram of the water flow).

Mussels are capable of pumping large volumes of water through their gills and can increase or decrease this rate depending upon the concentration of the particles in the water around them [4]. A 12-month old mussel is capable of filtering 2-3 litres of water per hour, whilst an adult mussel typically filters 6-9 litres of water per hour [6]. Pumping rates as high as 350 litres per day have been recorded for individual adult Greenshell™ mussels [6].

The gills filter potential food particles from the water. The particles are trapped in mucus produced on the gills, which is then moved to special **food transport pathways** at the ventral edge of each gill (known as the **ventral particle groove**) [2]. Cilia in the ventral particle groove convey the particle-laden mucus to the **labial palps**, where potential food particles are separated from unwanted particles. Potential food particles are transported into the mouth. Unwanted particles bound in mucus are dropped back into the inhalant chamber. This waste is known as **pseudofaeces** (pronounced "see-udo-fee-sees". *Pseudo* is Latin for false, so "pseudofaeces" means "false faeces" i.e. stuff that looks like faeces but isn't really because it hasn't passed through the gut.) Periodically, the pseudofaeces are ejected from the inhalant chamber by sudden and forceful closure of the valves (shells). This is sufficient to jet the rejected material out [2].

ACTIVITY 14

Remove the right valve from a live Greenshell™ mussel by cutting through the posterior adductor muscle (as you did in the previous exercise to look at the internal anatomy of the mussel). Try not to damage the mussel, particularly the gills, as you do this.

Place the mussel (left valve down) into a small container and fill with seawater until the mussel is just completely covered. Locate the region of the inhalant current, and drop some carmine dye into the current to see it moving into the inhalant chamber.

Next, pull back the right mantle to expose the gills, and drop some more carmine dye into the inhalant current. Watch the gills closely. After about 5 minutes you should be able to see the red carmine dye particles being caught, bound into the mucus, and moved along gill pathways. (Note you may need to add more drops of carmine dye if the movement is not clear.

Draw a picture with arrows showing the direction of the movement of particles (i.e. the food pathways) on the gills of a mussel.

What do mussels feed on?

Phytoplankton is the main food for mussels. Phytoplankton are tiny plants that float in the sea. They are made up of single cells or chains of cells. There are many different species of phytoplankton in the sea. Different species are different sizes. Adult mussels eat phytoplankton of a range of sizes, from very small (e.g. 1 micron, which is one-thousandth of a millimetre) to greater than 30 microns. Mussel gills can sort particles as small as 1 µm in size ("µm" is an abbreviation for "micron").

3A Feeding - continued

Mussels also eat particles that are smaller than phytoplankton, such as bacteria. Scientists are becoming increasingly interested in the role of bacteria as a food source for bivalves. Because they get stuck to the mucus on the gills, viruses (which are even smaller than bacteria) are also accumulated from the water by mussels. However, their role in mussel nutrition is unknown at present.

The gills are also able to absorb dissolved nutrients directly from the water [7].

Self Test Questions	**Element 3**
1. Describe how mussels capture potential food particles and transport them to the mouth.	
2. Before they enter the mouth, where are potential food particles sorted?	
3. What happens to the unwanted particles?	

3B The Reproductive Cycle – More about gonads

As discussed in Section 2, the **gonad** is the tissue that **produces eggs or sperm**. Egg and sperm production occurs in a seasonal cycle because it is related to **water temperature** and **food availability** [8], both of which vary with the time of year. These **cyclic changes in the gonad tissue** that relate to the **production and release of eggs and sperm** are called the **reproductive cycle**.

The gonad can form quite a large proportion of the total mussel tissue mass. Consequently, mussel farmers are generally very aware of changes associated with the mussel reproductive cycle because they impact on the condition (fatness) of the mussels. The fatness and appearance of the gonad, and what goes on inside the gonadal tissue, varies throughout the cycle. Each cycle includes **build-up of glycogen** in the tissue (glycogen is a complex sugar used by mussels as a way of **storing energy**), followed by the **use of the energy to form eggs and sperm**, and subsequent **release of eggs and sperm** into the water (called "**spawning**").

There are five stages in mussel gonad development:

1. ***Immature (or Resting) Stage***
2. ***Developing Stage***
3. ***Mature Stage***
4. ***Spawning Stage***
5. ***Spent Stage***

A description of each of these stages is given below:

Immature (or Resting) Stage:

In this stage special storage cells in the mantle and mesosoma accumulate glycogen, which is used as an energy source in the following stage. There are no eggs or sperm in the gonad. To the naked eye, the gonad tissue in the mantle and mesosoma appears creamy-white in colour, and of consistent texture. Food availability may impact on the rate at which mussels build up glycogen at this stage.

Developing Stage:

During the developing stage, spaces called **follicles** develop in the gonad tissue. The cells that line the follicles then produce the **gametes** (pronounced "gam-eets") [4]. "**Gametes**" is the scientific word for **eggs and sperm**. In Greenshell™ mussels the **sexes are separate** – that is, mussels are either female and produce eggs, or males and produce sperm [9]. (Not all mussels have separate sexes – for example, Blue mussels may be hermaphrodites, with both eggs and sperm being produced by one individual). Because eggs are orange-coloured, as eggs develop in the gonad the tissue becomes speckled with light orange colour, which gradually expands to a full orange colour as the number of eggs increases. The gonad of male mussels remains cream-coloured. **Temperature** is an important cue for the initiation of the developing stage - development of reproductive tissue only begins at temperatures greater than 11°C [10].

Mature Stage:

The mature stage is reached when the **gonads are filled with fully developed gamete**s (eggs or sperm). Under the microscope, the eggs in females appear as tightly packed polygon shapes, while in males the layers of sperm in the follicles are dense and compact [11]. Fully developed eggs are about 0.05 mm in size. To the naked eye, the mantle appears thick, and the mesosoma is large and swollen. The gonad of females is a bright orange colour. Male gonads appear mottled creamy white. Discharge tubules (tubes which carry the gametes out of the gonad at spawning) may appear like veins across the surface of the gonads (see Figures 8 and 9), and the gonad has a granular (grainy) appearance. The surface of the mantle and mesosoma is easily ruptured, "bleeding" out eggs or sperm.

Figure 7: Close-up of mature female gonad. (Buchanan 1999)

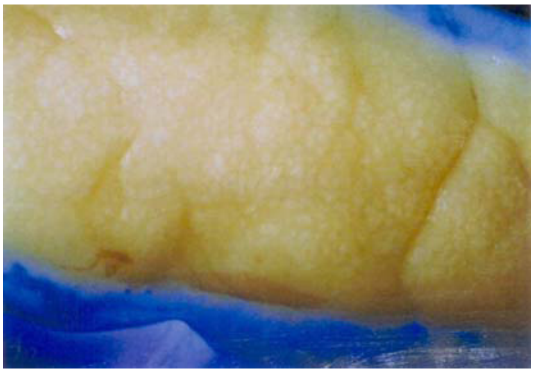


Figure 8: Close-up of mature male gonad. (Buchanan 1999)

Spawning Stage:

During spawning the gametes are discharged from the gonad – the eggs are discharged into the inhalant chamber and then jetted out into the water by a rapid closing of the shell, and the sperm is discharged into the exhalent current of the mussel. The beginning of **spawning** is **triggered by environmental cues** such as **changes in temperature, blooms of phytoplankton, storms, or stress** (including for example, stress caused by harvesting or transportation once harvested, which can cause problems for mussel farmers and processors). Spawning tends to be a communal event – the **presence of sperm** from one male in the water can trigger spawning in the rest of the population. Because mussels may not spawn out all the gametes at one time, the gonads can appear patchy in colouration during the spawning stage, with the discharge tubules still clearly visible.

Spent Stage:

The spent stage occurs after spawning, and only residual gametes and collapsing follicles are found in the gonad. The mantle and mesosoma are very thin (often translucent), and the dark brown gut region may be clearly visible in the mussel. This stage is followed by the immature stage (see above).

A female mussel may produce up to 10 million eggs in a season, and male mussels produce many more sperm [12].

Within a population of mussels there may be adults at a variety of different stages of gonad development all year round. However, Greenshell™ mussels tend to spawn mainly between spring and autumn. Spawning peaks in Marlborough mussels have been observed by scientists in August/September and March/April [11]. Studies at Ninety Mile Beach, in the north of the North Island (which is the area from which most of the mussel spat for the mussel farming industry is collected) show that most spawning occurs there from June to December [9]. Not all mussels spawn at the same time, and spawning condition may be maintained for several months. In summer the spawning is prolonged and most mussels rapidly develop more gametes after spawning [11].

3B The Reproductive Cycle – More about gonads - continued

Possibly because of differences in growing conditions (such as water temperature), the timing of the reproductive cycles differs slightly between mussels in Marlborough and those grown in Coromandel. Observation by mussel farmers suggests that the spring spawning peak may begin earlier in Coromandel (e.g. in July) and that spawning occurs throughout summer, with rapid development of gametes between summer spawning events.

So what does all this mean for mussel farmers? Obviously reproduction in mussels is crucial in supplying continuing generations of stock to farms, and a knowledge of the reproductive cycle assists in planning spat-catching activities. In addition, the condition of the gonad affects the marketability of mussels, with "fatter" mussels being preferred. Mussels in the spent stage are least marketable. Because mussels develop gonadal tissue more slowly after spawning in winter than in summer (particularly in Coromandel, where mussels condition rapidly in summer), the time when marketability of mussels is most limited is after the winter spawning event.

Self Test Questions **Element 3**

1. Describe what happens in the gonad at each of the stages of gonad development.
2. What are four environmental cues that can trigger spawning in mussels?
3. What does a mussel at the mature stage of the reproductive cycle look like?

3C Life Cycle

The basic mussel life cycle:

Mussels go through several different stages as they develop and grow from tiny, just-fertilised eggs through to much larger adults. At these stages they are not only different sizes, but in some cases also have different anatomy (i.e. their bodies look and work differently) and live in different environments. These stages form part of the **life cycle** of the mussel.

> ***Larval stages:*** The first stages in the life cycle of mussels are the **larval** stages. The larval stages of a mussel have different body shapes from adult mussels. **Mussel larvae** (mussels in the larval stages) are also different from later stages because they are **planktonic**, that is, they **float around in the sea**. The larval stages of mussels last about 3-6 weeks [7, 13, 14] and mussel larvae may be moved several hundred kilometres by currents [13]. This enables mussels to disperse to areas some distance away from the parent populations.
>
> ***Juvenile stage:*** After the larval stages, mussels **change in body shape** (this process is called "**metamorphosis**", pronounced "met-a-morf-o-sis") and become **juveniles**, which are **similar to miniature adults except that not all their organs are fully developed**. Small juvenile mussels are called **spat**.
>
> ***Adult stage:*** Juvenile mussels grow and mature to become adults. Mussels are regarded as being **adult** when they are **sexually mature** – that is, they are **able to produce eggs or sperm**.

Details of the mussel life cycle:

Following is a discussion of the different stages of the mussel life cycle. Pictures of different stages are provided in the following Figure 9.

The beginning of the life cycle:

The beginning of the life cycle occurs when adult mussels spawn. Mussels are **broadcast spawners**. This means that they **release their eggs and sperm** into the surrounding water [7].

Greenshell™ mussel eggs are about 0.05 mm (50 microns) in size [15]. Eggs are fertilized in the open water by sperm that are released from male mussels. A fertilised egg is known as a **zygote** (see Figure 9). After fertilisation, the cells of the zygote divide many times.

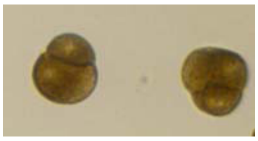
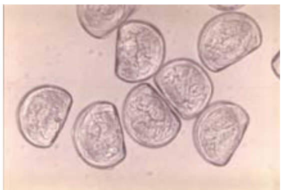
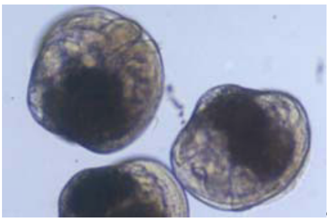
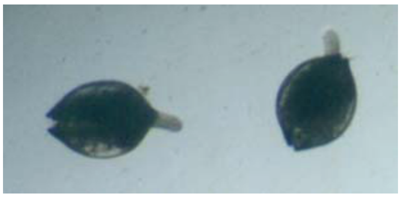
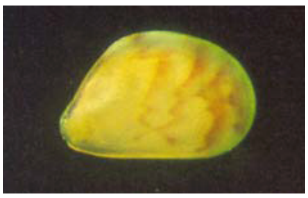
The first larval stage (Trochophore):

Once a sperm fertilises an egg, the fertilised egg grows by cell division (that is, one cell divides into two, the two cells divide into four etc). This cell division continues, and in about **five hours** there are thousands of cells in a ball, still the original size of the egg [2, 14]. This ball develops a ring of cilia around it, to become what is known as a **trochophore larva** (pronounced "tro-ko-for"). Beating of the cilia moves the trochophore through the water. Trochophore larvae are the **first swimming stage** in the life cycle of a mussel.

Trochophores do not feed, and have **no digestive system**. Instead they use up energy reserves that were stored in the egg before spawning. The **trochophore stage lasts about 1-2 days**, depending on the water temperature. (In general, development tends to be faster at higher temperatures).

3C Life Cycle – continued

Figure 9: The Stages in a Mussel Life Cycle

	Sperm ↘ ↙ Egg	
 a.	**Zygote**	
	↓ **Trochophore**	*Approx. 5 hours after fertilization*
 a.	↓ **Veliger (D-shaped)**	*1-2 days after fertilization 75 - 135 µm*
 b.	↓ **Veliger (Umbo)**	*136 – 250 µm*
 a.	↓ **Pediveliger**	*220 – 350 µm*
 a.	↓ **Settlement**	
 b.	↓ **Spat**	*> 0.3 mm*
 b.	↓ **Juvenile**	
	↓ **Adult (mature)**	*Approx > 1 year age*

a. Pictures courtesy of Cawthron Institute **b. Pictures taken from Jenkins (1985)**

3C Life Cycle – continued

The second larval stage (Veliger):

At the end of the trochophore stage, larvae develop two shells hinged together that enclose the body, and new organs [2]. Larvae at this stage are called **veligers** (pronounced "vell-i-jers"). The shells are initially shaped like a "D", with the straight edge of the "D" forming the hinge (see Figure 9). Because of their shell shape, early veligers are sometimes called "D" shaped or "straight-hinged" veligers. "D" shaped veligers are initially about 90 x 70 microns (0.09 x 0.07 mm) in size.

As a veliger grows, the shape of the shells changes and the initially straight hinge becomes more rounded. Eventually the shell develops a protrusion (bump) called the **umbo** (like on the valves (shells) of adult mussels) which extends beyond the line of the hinge. Veligers at this stage are often called "umbo" veligers. Umbo veligers grow from about 130 microns to 250 microns in size. The shells of veligers are transparent (if you look at them under a microscope you can see right through them to the organs inside).

Veligers do not yet have gills like juvenile or adult mussels, so they absorb oxygen directly through the surface of their bodies. They have a **simple digestive system** and a **velum**, (an organ fringed with cilia that they can extend out of the shell, used for **swimming** and the **collection of food particles**).

Like adult mussels, veligers **mostly feed on phytoplankton**, but they are also able to **absorb dissolved nutrients** directly from the water through the **surface of the velum** [7].

The velum has a band of long cilia that collect suspended food particles from the water [4]. Particles are then moved towards the mouth by the beating of shorter cilia contained in a special "food groove" that leads to the mouth. These cilia are able to sort and select food of the preferred particle size. In early veligers, particles of 1-2 microns in size (i.e. small phytoplankton) are preferred [2] but as veligers grow they are able to eat larger phytoplankton. Once the particles enter the stomach, further sorting occurs and unwanted particles can be passed directly to the intestine for removal. Food particles are digested in the stomach.

The cilia on the velum are also used to propel the veligers through the water. Veligers are not strong swimmers and are moved by ocean currents. However, they can swim enough to move up and down the water column in order to stay in water depths where phytoplankton are present.

The pediveliger stage:

At about 200 microns in size (0.2 mm), veligers develop a **foot** [14], and are known as "**pediveligers**" ("pedi" means foot, so "pediveliger" means veliger with a foot). In warm temperatures (>18 °C) this may occur as early as 2.5 weeks after fertilization, but takes longer in cooler temperatures [14].

The **foot** can be extended outside the larval shell, and has a **sensory function**. A pediveliger uses its foot to explore surfaces to determine whether they are suitable places to settle. The velum is still present at this stage and is used to swim between potential settlement sites. Feeding and digestion in pediveligers is the same as in the earlier veliger stage, although because they are bigger, larger particles can be consumed.

Pediveligers start developing gills that will be used for feeding and gas exchange once they change into spat. Late in the pediveliger stage, two dark-coloured "eyespots" develop. The function of these spots is not known, but their presence is an indication that the pediveliger is nearly at the stage when it will be able to make the change to spat.

Primary settlement and metamorphosis:

Settlement occurs when the pediveligers reach about 270-300 microns in size. The larvae look for a suitable filamentous substrate on which to settle, such as finely branching seaweed [16]. In the absence of suitable settlement surfaces, the pediveliger can remain in the water column for several weeks [7, 13].

3C Life Cycle – continued

Greenshell™ mussel larvae settle on a variety of coastal and drift seaweeds. A number of different factors impact on the selection of suitable settlement sites in addition to the structural form (for example, a finely branching form is preferred [16]). These include chemical factors (e.g. chemical attraction to sites where other mussels are present), biological factors and hydrodynamic processes (for example, water turbulence) [17]. Biological factors may vary between mussel species. For example, larvae of the blue mussel *Mytilus* tend to settle close to the water surface due to their preference for intertidal sites, whilst those of the Greenshell™ mussel tend to be more densely distributed deeper in the water column. In mussel farming, knowledge of the cues that mussels use in selecting settlement sites is important in designing spat-catching systems.

Settlement begins when the pediveliger larva attaches to a selected settlement surface by secreting **byssal threads**. Immediately after settlement the larva changes into the adult form. This change is called **metamorphosis**. At metamorphosis, the velum disintegrates, formation of the adult gill and labial palps is completed, and the organs of the mantle cavity change position [4]. Feeding does not occur during metamorphosis. Following metamorphosis **secretion of the adult shell begins** [4]. As a result of this, the shell changes from being **transparent to cream coloured**. The **methods of feeding** change to those present in adult mussels, and they start to **use gills for gas exchange** (e.g. oxygen uptake). At this stage the small mussels are known as juveniles or **spat.**

Juvenile stage

Small Greenshell™ mussel spat grow rapidly and quickly develop a **light green colouration with light brown markings**. As they grow, the **colour deepens** into that typical of adult mussels.

Early in the juvenile stage, spat can still move from one settlement site to another. In fact, studies have shown that the settlement sites preferred by very young spat (<0.5mm) are different to those preferred by larger spat, and that spat move from one site to another as they grow [17].

Spat less than 2 mm in size are still able to crawl around on their foot [14]. Greater distances can be covered when spat secrete threads of mucus which act like parachutes, enabling them to drift in water currents [7]. Greenshell™ mussel spat lose the ability to "**mucus drift**" when they are around 6mm in height [17].

Changing site preferences, combined with the ability to "mucus drift" may explain why abundant primary settlement on spat-catching ropes on mussel farms is often followed by high losses of spat over the following weeks.

Adult stage

Mussels are regarded as being **adult** when they are **sexually mature** – that is, they are **able to produce eggs or sperm**. Studies of Greenshell™ mussels collected from Ninety Mile Beach show that half of the mussels about 27 mm in length contained some gonadal tissue – so the development of gonadal tissue begins when mussels are still quite small [9]. Males and females become sexually mature at about the same size [9]. Sexual maturity in mussels is often reached by the first year of age [18].

Self Test Questions **Element 3**

1. Describe the life cycle of a Greenshell™ mussel (kutai, kuku). (Include a brief description of what each stage looks like, roughly how big it is at each stage, how it behaves at each stage (e.g. Does it swim? Anchor itself? etc), and how long each stage lasts).

2. a) How do trochophores get their nutrients and energy for growth?

   b) What do mussels eat at the other stages of their life cycle?

   c) Describe how mussel veligers feed.

   d) Describe how juvenile and adult mussels feed.

4. The Growth of Greenshell™ Mussels

4A What is growth?

Because it is related to the profitability of mussel farming, the growth of mussels is one of the most important aspects of mussel biology for a mussel farmer.

Growth is usually thought of as an **increase in size**. Very simply, the body of a mussel grows when its cells divide faster than they degenerate (die off). The mussel needs to increase the size of its shell to accommodate the increase in body size.

So what do you need to measure to observe growth? There are lots of different measurements that could be used – for example: an **increase in the size of the shell** (measured as an increase in the height, width, or length, or all three together), or the **weight of a whole mussel**, or the **length of the body itself**, or the **weight of the mussel tissue**. Scientists measure growth in shellfish in yet another way - as an increase in the **dry weight of tissue**. However, **generally there is a relationship between growth measurements taken in all of these ways, although this relationship may vary slightly with season.**

The **easiest way of measuring growth is to measure shell size**. Mostly there is a direct relationship between what is commonly called shell "length" in the mussel farming industry (that is, the distance from the umbo to the farthest edge of the shell – scientists call this "shell height") and the weight of the animal inside. (Note: If you can't remember where the umbo is, refer back to Figure 1).

ACTIVITY 15
Can you think why the relationship between shell length and the weight of the mussel inside might vary with season?

4B Shell production

Mussels increase the size of their shells by **laying down new shell** at the margin (edge) of the valve (shell). Most of this is laid down at the **posterior valve margin** (so the valve increases more in this direction). This new shell material is produced by the **outer fold of the mantle edge**.

The outer fold of the mantle edge lies in contact with the edge of the valve, and may be seen extending beyond the edge of the valve during periods of rapid growth. The **outer surface of the outer fold** utilises the calcium that is dissolved in seawater, and deposits it onto the edge of the valve to **make the calcium carbonate-protein structure of the shell**. The **inner surface of the outer fold** lays down the **periostracum.**

As the growth rate changes, rings (like growth rings in a tree) are formed from the continuing deposition of shell at the valve margin. Periods of slow growth may result in strong or concentrated lines that are evident as ridges on the shell. Such "checks" in growth are often observed by mussel farmers following reseeding, and it is quite common to see a ring on mussel valves that corresponds to the size that the mussel was during reseeding (See Figure 10).

Figure 10: ***Photograph of farmed mussel showing ring in shell caused by a check in growth (see arrow) (Photo: V. Seager).***

4B Shell production - continued

The **mantle** is also responsible for shell thickening - The entire outer surface of the **mantle** (not just the mantle edge) which rests against the inner shell surface produces shell which lines the whole interior surface of the valve, resulting in **shell thickening** [2].

4C Basic factors that affect mussel growth

The growth rate of mussels is not constant, but changes over time as a result of a variety of different factors.

Age:
The most fundamental change in growth in mussels is related to their age. Mussels of **different ages grow at different rates**. When they are small, their size rapidly increases. However, growth in adult mussels slows as they become older. Most living organisms, including humans, follow this basic pattern of growth (think of how much our growth slows once we get past our teenage years – if we kept growing at the same rate throughout our lives the world would be populated with giants!).

A scientific study of mussels in suspended culture (in the Cook Strait region)[19, quoted in 10] found that mussels grew about 140 mm in the first 18 months, and only about 55 mm in the following 2 years. If there were a market for giant mussels, it would be useful to take into account this basic growth pattern when considering whether it would be economically worthwhile to hold mussels on a farm to grow to the required large size.

Within this general pattern of growth, rates of growth in mussels are a complex function of ***temperature, food availability, food quality,*** *and* ***reproductive cycle****.* ***Stress*** *may also impact on growth rate.*

Temperature:
Mussels are **cold-blooded animals** ("poikilotherms" is the scientific name for cold-blooded animals), which means that they have **no internal temperature regulation**. Their body temperature is therefore the same as that of their surroundings.

In general, chemical reactions proceed at a faster rate at higher temperatures. Within limits, this is also true of the chemical reactions involved in mussel metabolism (that is, all the chemical reactions that keep the mussel functioning). As water temperature increases, so does the filtering rate and metabolic rate of mussels (and hence the potential for a higher growth rate). The limit within which this holds true is the temperature tolerance range of the mussel – if the temperature is too hot or too cold, the mussel will cease to function and die.

The areas in New Zealand in which Greenshell™ mussels live include temperatures in the range 5.3°C - 27°C [10]. Although they may get stressed at temperatures in the high end of this range, basically **increased growth rate could be expected with increasing temperature over most of this range**.

Food availability:
Food availability also affects mussel growth, with a generally higher growth rate when food is available in preferred quantities. Food availability depends on the density of food particles in the water available to the mussels, combined with the level of competition for food. Mussels need not too little, and not too much, phytoplankton present in the water to achieve optimal growth. Obviously, if there is insufficient phytoplankton in the water to feed the number of mussels present, they will starve and have no energy to grow. (This is one way in which stocking densities on mussel farms can impact on mussel growth rates). As mussels are filter feeders, higher concentrations of phytoplankton in the water will require lower filtration rates to take up the maximum volume of food and enhance growth. Mussels can alter their filtration rates based on the concentration of plankton in the water [4]. However if phytoplankton levels are too high, mussels may have to use a lot of energy getting rid of excess food particles, which in turn may lower their growth rates.

Because phytoplankton densities vary seasonally (they are influenced by things like water temperature and sunlight levels), seasonal changes in growth of mussels may arise as a result of food availability.

4C Basic factors that affect mussel growth - continued

Food quality:
The presence of optimal densities of phytoplankton in the water is not necessarily sufficient for good nutrition of mussels – they require a balanced diet, with different kinds of phytoplankton providing different essential nutrients. Some species of phytoplankton are difficult to digest, or have very little food value. In addition, the presence of high numbers of non-food particles, such as suspended sediment after storms or heavy rainfall, can result in the mussels having to use energy in sorting and getting rid of unwanted particles, resulting in lower growth rates.

Optimal food quality thus includes having a low proportion of non-food particles in the water and a good mixture of phytoplankton types giving a nutritionally varied and adequate diet.

Reproductive cycle:
The reproductive cycle of mussels also affects their seasonal growth pattern, since this determines the way in which energy is apportioned for growth. The impact of this depends on the age of the mussel. In the early part of their life, a large part of a mussel's energy is directed into growth, and none into reproduction. As the mussel matures, an increasing amount of the energy budget is allocated to the production of gonad, slowing the increase in overall size of the animal.

Stress:
Stress, which can impact on the metabolism of shellfish, can cause the growth rate of mussels to slow. Mussel stress can be caused by a variety of different things, including blooms of phytoplankton that result in low oxygen levels in the water, toxic phytoplankton blooms, low salinity, or disease. Handling on farms (e.g. stripping off ropes, being out of the water, reseeding) can also result in stress. The checks in growth associated with reseeding are a good example of changes in growth rate associated with farm handling. While some of this impact may be associated with stress, reseeded mussels must also use energy in both repositioning and producing new byssal threads (beard) for attachment, and this may also reduce their growth rates.

At any one time, **all these different factors interact to determine the growth of mussels**. At any one place, growth rates in mussels may vary from year to year as one or several of the determining factors vary. Because of different environmental conditions, some areas may be better suited to fast growth in mussels than others. For example, on farms in the Coromandel region, mussels of target harvest size (80-115 mm) are typically produced in 7-14 months following reseeding, while in the Marlborough region it takes 14-24 months to achieve the same size.

Self Test Questions **Element 4**

1. Describe two different ways that mussel growth can be measured.
2. What part of the mussel produces the shell at the shell margin?
3. What part of the mussel produces shell thickening?
4. Name four things that can influence the pattern of growth in mussels, and describe how each of these factors influence growth rate.

5. Potential Health Issues

5A What is disease?

Disease can be defined as **an abnormal condition that affects the performance or vital functions of the affected animal** [20].

Viruses, bacteria, fungi, protozoa, (all of which are organisms that are microscopic in size) and parasites of a variety of types and sizes can cause infectious diseases. Infectious diseases can often be passed directly from one organism to another (e.g. mussel to mussel, oyster to mussel).

Non-infectious diseases cannot be passed from one organism to another, but are caused by external factors such as nutrition (e.g. poor phytoplankton availability or quality), environment (e.g. toxic phytoplankton blooms, smothering by competitors) or physical trauma (e.g. predator damage, reseeding shell damage).

Note that disease is not the only cause of mortality on mussel farms – for example, predation by birds, fish and flatworms can also cause mussel mortality (see Diggles *et al.* (2002) [20] for more information on flatworms that cause mortality in mussels).

5B How to tell if a mussel is sick

In any farming situation where one species is kept together in large numbers the risk of disease outbreak is greatly increased. We are lucky in New Zealand that we have a relatively disease-free population of mussels for farming and these do not appear to be badly affected by native diseases. However, disease is always a risk to the mussel farming industry, and it can be useful to be aware of the kinds of diseases that may affect farmed mussels. Following is a list of the kinds of symptoms that might indicate the possibility of disease in mussels:

- high levels of mortality;
- mussels gaping wide open immediately after they are taken out of the water;
- the presence of disease-causing animals on or in the mussels;
- mussels unexpectedly fail to grow or fatten;
- opened mussels have lesions (sores) on the body;
- opened mussels appear to be an unusual colour or appearance;
- the gills of mussels appear damaged.

5C What to do

Diseases in mussels are difficult to manage compared, for example, to treatment of illness in humans. You can't immunise each one, or give them antibiotics out on the farm! Some diseases can be minimised by managing the growing conditions of the mussels (for example, by minimising mussel stress). However, many of the diseases caused by micro-organisms like bacteria and viruses cannot be effectively treated once they are present. In these cases, the only course of action may be prevention of the spread of the disease by preventing the movement of mussels from one growing area to another.

Although New Zealand mussel farming areas are relatively free from serious diseases at present, there is always the potential that serious mussel diseases may occur. The response required by mussel farmers to mussel disease varies depending on whether the disease is one that is commonly observed in New Zealand, or one that is unusual or has not been seen here before.

Response to common diseases:

Some things that cause health issues in mussels are relatively common or well-known within the New Zealand mussel farming industry (for example, mud-worm infestations). In such cases, recommended management practices for dealing with such issues will already be established within the mussel farming industry, and these practices should be implemented.

5C What to do - continued

Response to abnormal or unexplained illness:

The observation of abnormal or unexplained illness or mortality is potentially a much greater cause for concern. Identifying the cause of such problems, and if possible solving them, is a job for people with expertise in shellfish diseases.

- **Quick action can prevent new diseases from spreading, so don't hang back if you think there is a potential problem –** its better to be reassured that there is no problem than to do nothing and end up with widespread mussel mortality or illness.

- **Talk to the right people:**

    - If you are a new mussel farmer and not sure whether what you are observing is unusual or not, ask advice from several more experienced people in the industry (other farmers or mussel processors).

    - Talk to members of your local Delivery Centre to find out how widespread the problem is in your area.

    - If it seems to be an unusual or new health issue, seek early advice from a scientist with expertise in shellfish diseases (the NZ Marine Farming Association will be able to provide information on who to talk to). Depending on the type of disease, MAF Biosecurity may need to be informed of the problem.

    - Use established channels of communication within the industry – uncontrolled media releases before the nature of the problem has been properly established could result in significant unnecessary harm to the industry (see Section 5.4 below).

- **If there is a significant problem, follow the advice of the experts and regulatory officials** – for example, if controls on the movement of shellfish from one area to another are instituted, make sure that you comply to prevent the problem from spreading.

Remember, it is the people working with mussels out on the farm and in the processing factories that are the "eyes of the industry". If you notice unusual symptoms in mussels out on the farm or in the factory, make sure that you inform the management of your organisation so that they can take appropriate action. If you are the management, listen to your staff and take action quickly.

5D Why is it important to take action?

Prompt and appropriate action in the event of mussel illness can **reduce the economic impact on individual mussel farmers and the mussel industry as a whole.**

Mussel disease has the potential to have very drastic impacts on mussel production, with consequent failure of mussel farming businesses and job losses. The **economic impact** of disease through **loss of production or a decrease in mussel quality** could be **minimised by early detection and containment** (i.e. prevention of the spread of disease from one area to another).

The economic impact of disease events in the mussel industry are not just due to loss of production: the presence of some diseases in mussel farming areas can be justifiably, and sometimes unjustifiably, used as a barrier to trade with other countries i.e. **other countries may prohibit the import of New Zealand mussels**. For this reason **it is important that accurate information is released to our trading partners through the appropriate channels** (i.e. MAF and NZ Food Safety Authority).

These impacts can be minimised if the problems are recognised at an early stage.

5E Diseases that impact on mussels in New Zealand

To date, New Zealand appears relatively free of diseases affecting Greenshell™ mussels, and significant mortality arising from disease is rare.